Mangled Extremity

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Objectives: At the completion of this module fellows will be able to:

1. **Define what is meant by a mangled extremity.**
2. **Describe the factors that determine limb salvage vs. amputation.**
3. **Describe the operative techniques for management of the mangled extremity.**

Background

- The definition of a mangled extremity remains imprecise, but involves any extremity with significant injury to all components: vascular, bone, nerve and soft tissue. Mangled extremity injury often involves Gustillo type 3b (wound > 10 cm, extensive periosteal stripping, requires free flap coverage) or 3c (vascular injury requiring repair) fracture patterns.
- Capabilities for limb salvage must take into account hospital and physician resources.
- No scoring system has proven successful in predicting outcomes.
- A multi-disciplinary approach including trauma, orthopedics, vascular, and/or plastics/microsurgery is often required.
- Optimal outcome requires the trauma surgeon to evaluate all factors including hemodynamic stability, co-morbidities, and life threatening injuries before determining the appropriate choice between limb salvage procedures and amputation.

Evaluation/Diagnostics

- If active bleeding from the extremity is identified, a tourniquet should be placed for hemorrhage control if direct pressure is ineffective.
- Diminished and/or asymmetrical pulses and/or an ABI<0.9 should prompt further vascular evaluation such as a CTA of the extremity or digital subtraction angiography in the hemodynamically stable patient.
- The absence of pulses after the limb has been grossly re-aligned should prompt urgent intervention. If there are multiple fractures/injury sites, a preoperative CTA can be performed if done expeditiously. Alternatively, an intra-operative arteriogram can be performed. This can be done using a standard femoral arterial line catheter, micropuncture catheter, or large-bore butterfly needle after open exposure of the vessel with the patient on a fluoroscopy-compatible table. A hand-injection of 10cc of full strength contrast can be utilized for several successive images but if renal impairment is present 50% dilution of contrast with normal saline can give adequate images. A vascular C-arm that can perform digital subtraction angiography (DSA) is optimal.
- A complete neurologic exam of the extremity is mandatory to delineate preserved function.
- Plain radiographs of the extremity should be obtained.
- The MESS Score (Mangled Extremity Severity Score) is probably the best known scoring system. It takes into account the degree of limb ischemia, patient age, extent of shock, and mechanism of injury. However, no scoring system is predictive of limb salvage success and therefore should not be used in isolation to make any treatment decisions.

- The absence of plantar sensation on physical exam should never be used as the determining factor to perform an amputation. The anatomic status of the nerve is critical and should be assessed intra-operatively.

Management

- Fractures should be reduced and splinted prior to documenting the definitive pulse exam.
- Administer antibiotics as quickly as possible.
    - Options include:
        - Cefazolin plus an aminoglycoside.
        - Ceftriaxone alone.
        - Clindamycin plus aztreonam if PCN allergic.
        - If it is a farm injury, consider high dose PCN to address the risk of clostridial contamination.
- Tetanus should be administered as indicated.
- Attempted debridement in the emergency department is contraindicated.
- Open fractures should be covered in the ED with a sterile saline dressing to prevent further contamination.

Operative Technique

- Limb salvage should only be performed if the hemodynamic status of the patient safely allows for the procedure. Life comes before limb in unstable patients.
- There are very few absolute indications for an immediate amputation but may include total or near total amputation, anatomic disruption of the sciatic or tibial nerve and/or loss of plantar skin/soft tissue, and/or the presence of a crushed ipsilateral foot injury. The magnitude of the soft tissue injury is a major factor in the determination of limb salvage.
- If an amputation must be performed, every effort should be made to preserve as much length with associated viable soft tissue. At least 10 cm of tibia below the knee joint is needed for an optimal prosthetic fit. There are soft tissue coverage options for the distal stump; therefore, soft tissue coverage alone should not be the deciding factor for the level of amputation.
- When performing limb salvage, priorities should include:
    - Hemodynamic status.
    - Revascularization, either with a temporary intraluminal shunt or definitive management. Consider shunting the arterial injury especially with longer ischemia times/need for resuscitation.
    - Fracture reduction/ temporary stabilization with external fixation to regain/maintain gross length, rotation, and alignment.
    - Fasciotomy should be considered for those with prolonged ischemia, a concomitant venous injury, or a significant crush component.
    - Tissue debridement – this may require multiple operative debridements.

Postoperative Management and Potential Complications

- The most common complications in patients with limb salvage are infection and non-union.
- In patients undergoing amputation, infection is the most common complication.
- Patients with significant contamination should return to the operating room 24-48 hours after initial debridement to ensure devitalized tissues have been completely excised.

Long-term Outcomes

- Predictors of poorer outcomes after either amputation or limb salvage for a mangled extremity include low educational level, race, poverty, poor social support, lack of private health insurance, smoking, and involvement in disability-compensation litigation.
- At 2 years, the number of patients returning to work is similar between the amputation and limb salvage groups.
- Lower limb reconstruction is more acceptable psychologically to patients with severe lower limb trauma compared with amputation, but the physical outcome for both management pathways is essentially the same.
- Patients undergoing limb salvage will often require more hospitalizations and complex reconstruction.
- Regardless of whether limb salvage or amputation is chosen, the long term outcomes of mangled extremities are not good for either group and depend to a large degree on factors not related to the treatment of the injury. Salvage requires longer time in the hospital, more operations and has more associated complications. Long-term costs are higher for amputations when the cost of prosthetics is included.

Special Considerations: The mangled upper extremity

- Like lower extremity injuries, no scoring system predicts the likelihood of salvage of upper extremity injury.
- Important differences exist between upper and lower mangled extremity injuries:
    - Critical time for reperfusion is longer in the upper (8–10 hrs.) versus the lower extremity (6 hrs.)
    - A transtibial amputation carries a much better functional prognosis than transradial amputation as upper extremity prostheses are less functional than those of the lower extremity.
    - Shortening of the humerus up to 5 cm to reduce soft-tissue defects is well tolerated.
    - Nerve reconstruction in the upper extremity can be performed successfully while major nerve injury in lower extremity nerve is considered an indication for primary amputation.

Pearls from the Experts: Drs. Shahram Aarabi, Kaj Johansen, Malcolm Smith, and Philip Stahel

- Vascular compromise including muscle ischemia caused by compartment syndrome needs immediate management
- Reduction of bony displacement often restores vascularity and must be done first.
- If judged unsalvageable by a multidisciplinary team, amputation is appropriate and should not be considered a failure.
- Overall the outcome of extreme salvage and amputation are the same.
- The functional salvaged limb is the best outcome but the poor functioning one can be a massive problem leading to major investment in the limb by both the patient and surgeon; in the worst situation the patient ends up unemployed, addicted, divorced and destitute.
- If salvageable, the best management needs good debridement, stable fixation and early soft tissue care. Ideally a full debridement is accomplished during the first operative case; the second visit to the OR should be for definitive soft tissue coverage.
- Primary extremity amputation for a mangled extremity is rarely indicated, unless for a "life-for-limb" procedure in polytrauma patients "in extremis". In absence of an acutely life-threatening scenario, most mangled extremities are safely managed by initial "damage control" protocols including external fixation, soft tissue debridement, vascular repair and fasciotomies as indicated.
- Prophylactic fasciotomies distal to the level of an acute vascular injury is indicated to prevent ischemia/reperfusion-induced compartment syndrome secondary to successful vascular repair.
- Enforce immediate diagnostic workup for suspected vascular injury associated with a "mangled extremity" (either by CT-angiogram or "on-table" angiogram in OR in conjunction with surgical exploration) in presence of one of the following:
  - Equivocal or abnormal pulse exam and ankle-brachial-index (ABI) <0.9
  - Presence of one of 5 clinical "hard signs" of acute vascular injury: (1) Active or pulsatile hemorrhage; (2) Pulsatile or expanding hematoma; (3) Clinical signs of limb ischemia; (4) Diminished, asymmetric or absent pulses; (5) Bruit or thrill, suggesting AV-fistula.
- Keep high level of suspicion with low threshold for further diagnostic workup (see above) in presence of one of 5 clinical "soft signs" of acute vascular injury: (1) Asymmetric extremity blood pressure (i.e. ankle-brachial index < 1.0); (2) Stable and non-pulsatile hematoma; (3)Proximity of a penetrating wound to a major vessel; (4) Peripheral neurological deficit; (5) Presence of shock/hypotension.
- Keep high level of suspicion for a popliteal artery injury (>30%) in presence of high-energy trauma mechanism about the knee (knee dislocation, high-energy distal femur or proximal tibia fracture).
- Lower extremity injury level distal to the arterial trifurcation (e.g. ankle or foot injuries) is rarely associated with acute vascular compromise due to sufficient blood flow by anterior / posterior tibial or peroneal artery.
- Immediate reduction of displaced fractures or joint dislocations by axial traction facilitates blood flow to the injured extremity. Further work-up is determined on post-reduction vascular exam (as above).

- Pitfalls:
  - Pulse exam alone is not a sensitive tool for predicting or excluding a significant vascular injury.
  - Intimal arterial injuries are frequently missed and may lead to delayed vascular occlusion and ischemia. Suspect intimal injuries in cases when pulses are initially absent and return to normal, equivocal pulse exam, and dopplerable but non-palpable pulses. When in doubt, proceed with early diagnostic workup (CT-angiogram or on-table angiogram).
  - Collateral perfusion to the upper extremity represents a major diagnostic pitfall for upper extremity vascular injuries (in contrast to lower extremity vascular injuries). Patients with significant injuries to axillary or brachial artery may present with intact pulses and normal capillary refill distal to the injury site resulting from collateral perfusion. When in doubt, initiate diagnostic workup as outlined above.
  - Do not assume released compartment pressures in open fractures with partial fascial disruptions. Acute compartment syndrome requires a formal 4-compartment fasciotomies also in presence of open fractures and mangled limb.
  - Delayed development of compartment syndrome may represent a surrogate marker of a missed vascular (intimal) injury and requires immediate decompressive fasciotomies and diagnostic vascular workup.
- Fasciotomies are considered contraindicated in presence of "crush" injuries which represent a challenging differential diagnosis to acute compartment syndrome.
- ME patients will be almost certain to require multiple operations, and will sustain diverse complications, prolonged hospital lengths of stay and even lengthier periods of rehabilitation.
- Early in such patients' emergency room or hospital course, initial decision-making should include an honest answer to the question "Can we manage this problem here?" If not, resuscitate, stabilize/realign fractures, revascularize if necessary and transfer.
- The nature of these patients' injury mechanisms commonly results in concurrent major craniocervical or truncal injuries. Such injuries' management always takes priority (although it is sometimes possible to realign a fracture or insert a temporary shunt while a craniotomy or a thoracotomy is being accomplished).
- The orthopedists will want to get dislocated joints or fractured long bones realigned ASAP. But if it's ischemic, the ME must be revascularized first, if not by fracture/joint realignment then by insertion of a temporary arterial shunt.
- We have found emergency department or OR duplex sonography to be a useful tool to demonstrate whether and, if so, where extremity arteries have been traumatically occluded. This enables accurate cutdown, arterial exposure and shunt insertion for rapid limb revascularization. CTA or early intraoperative arteriography can provide similar information.
- If the limb is ischemic do NOT let the orthopedists talk you into letting them go first – "It will take me only 20 minutes to get an ex-fix in place!" In our experience, in even the best and most skilled of orthopedic hands a straightforward external fixator placement takes 45-60 minutes. Get a shunt in place and then the ortho folks can take all the time they want at fracture fixation (and can carry out a much more complete and accurate wound debridement while they're at it!).

- Definitive wound coverage (e.g. advancement or rotational or free-flap coverage) is not warranted or prudent at the initial operation (WoundVac or other such devices generally should suffice). But the relevant ortho or plastic/reconstructive surgeons should be involved early in such cases to be sure that later flap options are not compromised by initial incisions or debridements.
- Early decision-making in cases of severely-damaged extremities should try to discern whether the limb IS in fact salvageable. This is because markedly increased morbidity, reoperations, prolonged length of stay and disability attend a decision to pursue limb salvage when in fact a primary amputation should have been performed.
- Numerous scoring systems have been devised to try to facilitate such early decision-making. The MESS (Mangled Extremity Severity Score), reported initially in 1990, is the most commonly used. Following multiple technical advances over the subsequent 25 years its original "cut-point" (MESS value of 7 or greater) is now obsolete and is being recalibrated (recent data suggest a MESS value of 8 or greater warrants primary amputation). But the four clinical variables which comprise the MESS – soft tissue/skeletal injury, ischemia, shock and age/medical comorbidities – remain relevant.
- We continue to believe that demonstrated transection of the sciatic or tibial nerve (NOT just a preoperative nerve deficit on physical examination) warrants primary amputation. Recent case reports of functionally successful lower extremity neurorrhaphy in children suggest that a more liberal approach to efforts at limb salvage in pediatric ME victims may be appropriate.
- Principles of limb salvage in mangled UPPER extremities remain sharply different from those for lower extremities. Acceptable "warm ischemia" time is longer, limb-length discrepancy is much less concerning and, because upper extremity prosthetics remain primitive in the context of what they need to do, salvage of even an immobile, numb, insensate upper extremity is often better than even the very best upper extremity prosthesis.

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